STUDY ON TRANSMISSION CONGESTION MANAGEMENT FOR RESTUCTURING MARKET

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Special dedication to
my beloved husbands (Mohammad Wafi), family especially my mother (Sapora),
supervisor, friends and person who have encouraged, guide and inspired me throughout
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ABSTRACT

The electric power industry has over the years been dominated by large utilities that had overall authority over all activities in generation, transmission and distribution of power within its domain of operation. There were two conditions that are investigated in this research, uncongested and congested condition. The uncongested are condition were there no limitation to buy from any company that more cheap cost than during congested. While, congestion are one or more transmission lines reach their thermal limit and unable to carry additional power, a more expensive generation unit will be scheduled to serve the load. Since the cheaper generators could not reach the load location due to congestion. There were two generic approaches using in this thesis, first uniform market clearing price and locational marginal price (LMP). The uniform market clearing price is define as no transmission bottleneck and losses present during the transportation of the electricity, the cheapest power producer will be selected to serve the loads at all locations and therefore, the electricity price will be the same across the grid. While the LMP is define as the marginal cost of supplying the next increment of electric energy at a specific bus considering the marginal cost and physical aspects of transmission system. In other words, the LMP is the cost to serve one additional MW of load at a specific location, using the lowest production cost of all generators, while observing all transmission constraints. Furthermore, the LMP can be decomposed into three parts: marginal energy price, marginal loss price, and marginal congestion price. The result and analysis has been discussed in this research by comparing between two approaches in different condition. The results obtained are analyzed for further improvements and recommendations.

ABSTRAK

Industri tenaga elektrik telah sekian lama didominasi oleh utiliti yang besar dan mempunyai kuasa mutlak ke atas semua aktiviti penjanaan, penghantaran dan pengagihan kuasa dalam operasi. Terdapat dua keadaan yang akan dibincangkan dalam kajian ini iaitu keadaan tiada kesesakan dan kesesakan. Di mana tiada kesesakan adalah keadaan tidak mempunyai had untuk membeli daripada mana-mana syarikat yang menawarkan kos lebih murah daripada keadaan kesesakan yang mempunyai had. Di mana, kesesakan adalah satu atau lebih talian penghantaran mencapai had terma dan dapat tidak dapat menghantar muatan kuasa tambahan , tetapi unit penjanaan menjadi lebih mahal akan dijadualkan untuk berkhidmat pada pengguna. Oleh itu, penjana yang lebih murah harganya tidak dapat dihantar pada lokasi pengguna kerana berlaku kesesakan. Terdapat dua kaedah yang akan digunakan di dalam tesis ini , harga pasaran seragam dan harga marginal pada bas (LMP). Harga pasaran seragam adalah apabila tiada kesesakan dan kehilangan kuasa hadir semasa elektrik penghantaran, pengeluar tenaga yang paling murah akan dipilih untuk berkhidmat kepada pengguna di semua lokasi dan oleh itu, harga elektrik akan sama di seluruh grid. Manakala LMP adalah kos marginal yang membekalkan kenaikan tenaga elektrik seterusnya pada bas tertentu mempertimbangkan kos marginal dan aspek fizikal di talian penghantaran. . Dalam erti kata lain, LMP adalah kos untuk bagi pertambahan satu MW beban di lokasi yang tertentu, menggunakan kos pengeluaran yang paling rendah daripada semua penjana dengan mengambil kira semua kesesakan dalam penghantaran Di samping itu, LMP boleh dihuraikan kepada tiga bahagian: harga marginal tenaga, harga kerugian tenaga , dan harga kesesakan marginal. Hasil dan analisis, dalam kajian ini telah membincangkan perbandingan di antara dua kaedah dalam keadaan yang berbeza. Keputusan yang diperolehi dianalisis untuk penambahbaikan dan cadangan selanjutnya di masa hadapan.

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LIST OF SYMBOLS AND ABBREVIATIONS

DF	-	Delivery factor
F_T	-	Objective function
ELD	-	Economic dispatch
GSK	-	Generator Shift Factor
ISO	-	Independent System Operators
MCP	-	Market clearing price
NG	-	Set of all generating units including the generator on the slack
P_D	-	Total system load
P_G	-	Generation power
PL	-	Network losses
β	-	Constraints cost
Ɛ	-	Energy balance
λ	-	Lagrangian multiplier

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CHAPTER 1

INTRODUCTION

1.1 Overview restructured electrical power system

The electric power industry has over the years been dominated by large utilities that had overall authority over all activities in generation, transmission and distribution of power within its domain of operation. Such utilities have often been referred to as vertically integrated utilities. Such utilities served as the only electricity provider in the region and were obliged to provide electricity to everyone in the region.

The utilities being vertically integrated, it was often difficult to segregate the cost incurred in generation, transmission or distribution. Therefore, the utilities often charged their customers and average tariff rate depending on their aggregated cost during a period. The price setting was done by an external regulatory agency and often involved consideration other than economics. Figure 1.1 shows the typical structure of a deregulated electricity system with links of information and money flow between various players.

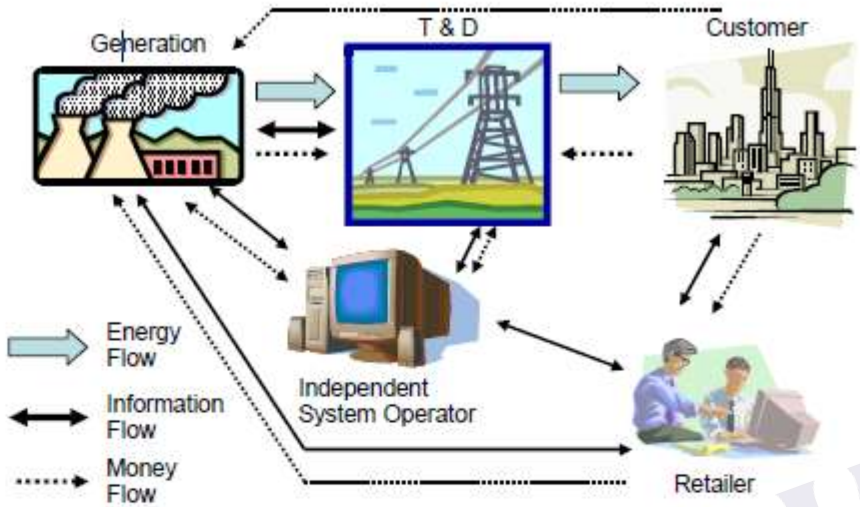

Figure 1.1: The typical structure of a deregulated electricity system

The configuration shown in the Figure 1.1 is not a universal one. There exist variations across countries and systems. A system operator is appointed for the whole system and it is entrusted with the responsibility of keeping the system in balance to ensure that the production and imports continuously match consumption and exports. Naturally, it was required to be independent authority without involvement in the market competition nor could it own generation facilities for business. This system operator is known as Independent System Operators (ISO). Customer does its transitions through a retailer or transacts directly with the generating company, depending on the type of a model. Different power sellers will deliver their product to their customers (via retailers), over a common set of T&D wires, operated by the independent system operator (ISO).The generators, T&D utility and retailers communicates with the retailer, demanding energy. The retailer contacts the generating company and purchases the power from it and makes it transferred to its customer's place via regulated T&D lines. The ISO is the one responsible for keeping track of various transactions taking place between various entities [1].

In the regulated environment, the electricity bill consisted of a single amount to be paid towards the generation, transmission and all other costs. But, in the restructured environment, the electricity price gets segregated into the following [2]:

1. Price of electric energy
2. Price of energy delivery
3. Price of other service such as frequency regulation and voltage control, which are priced separately and charged independently but may not to be visible in the electricity bills.

1.1.1 Main condition in deregulated market

There were two conditions that will discuss in this chapter, uncongested and congested condition. The uncongested are condition were there no limitation to buy from any company that more cheap cost than during congested. While, congestion are one or more transmission lines reach their thermal limit and unable to carry additional power, a more expensive generation unit will be scheduled to serve the load since the cheaper generators could not reach the load location due to congestion. Congestion management is an integral part of a properly designed electricity market, even though wholesale energy prices are its most visible piece. Consequently, electricity prices at this location will increase since it is served by the more expensive power producers. In addition to transmission congestion, power transmission losses also contribute to the varying prices at the different locations. For instance, a load, connected to the grid through a higher resistive transmission line, will be subject to a higher price since more electricity is lost during transportation, as opposed to the case of a lower resistive line. For a healthy electricity market, the physical aspect of power networks such as transmission constraints needs to be taken into consideration in overall market design [2][3].

1.1.2 Transmission cost calculation

There were two generic approaches using in this thesis, first uniform market clearing price and locational marginal price (LMP). The uniform market clearing price are when there is no transmission bottleneck and losses present during the transportation of the electricity, the cheapest power producer will be selected to serve the loads at all locations and therefore, the electricity price will be the same across the grid. While the LMP, is the marginal cost of supplying the next increment of electric energy at a specific bus considering the marginal cost and physical aspects of transmission system. The LMP can be decomposed into three parts: marginal energy price, marginal loss price, and marginal congestion price. These three parts represent the marginal cost associated with energy, loss, and congestion respectively. The reason that the LMP is split into three components is that the marginal congestion component is used to calculate congestion revenue and the value of the FTR [4]. Figure 1.2 shows the flow of transmission cost for this thesis.

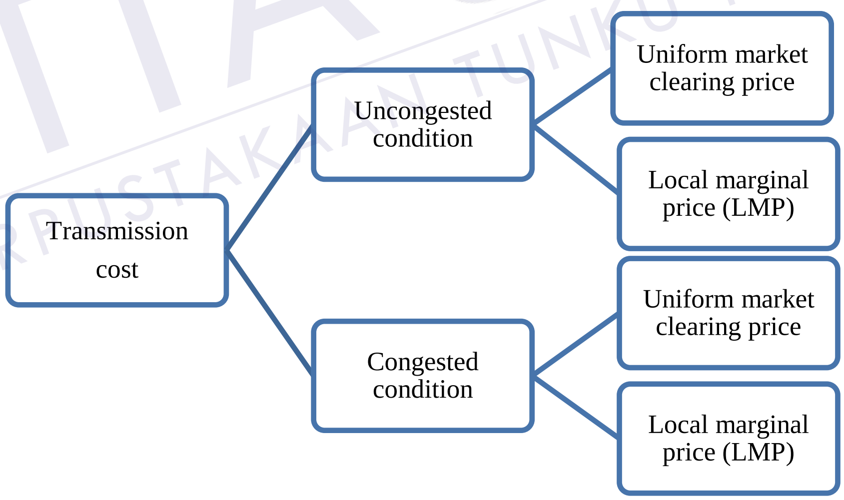

Figure 1.2: The flow of transmission cost for this thesis

1.2 Problem statements

Deregulation in power industry is a restructuring of the rules and economic incentives that government set up to control and drives the electric power industry. There are issues that arise in restructured market which is congestion. A transmission congestion charge is incurred when the system is constrained by physical limits. So a reasonable transmission pricing method should provide some economical signal to reflect the charge due to the physical constraints.

Through this project, there are two approaches to calculate the total cost during uncongested and congested condition that are uniform market clearing price and local marginal prices. By calculate the total cost it will shows the different price between this two approaches. The economical approach is chosen to serve the electricity at the load.

1.3 Objectives

The goals of this project are:

1. To minimize the generation cost by calculate for total price charge to generator and customer during congested and uncongested condition by using two approaches.
2. To show the different between the two approaches during congested and uncongested condition that more economical.

1.4 Scopes

The primary scope of this project is to calculate for total price to generator and customer during congested and uncongested condition in restructured electricity market by using two generic approaches. The first approach is by using uniform market clearing price and the second approach is using locational marginal prices (LMPs), both of which are derived from generators offers to sell electricity. Then from the calculation, the price during congested and uncongested condition will compared between this two approaches.

1.5 Overview of the thesis

Chapter 1 discuss the general background of the thesis, overview of deregulated market, the restructuring models and main entities of electricity market. This chapter also gives the problem statement, the objectives and the scopes of the project.

Chapter 2 gives the information of power system economic operation overview, problem of economic dispatch without considering network losses and considering network losses. This chapter also discuss about optimal power flow, the basic model of OPF and the objective functions and constraints in OPF.

Chapter 3 discuss the issues involved in deregulated market, network congestion, effects on network congestion and transmission congestion cost calculation. In transmission congestion cost calculation discuss on uniform market clearing price method (MCP) and local marginal price (LMP) method. Besides that, this chapter also shows example of two busses calculation using this two approach (MCP and LMP) within two conditions which are network ignoring congested and network considering network congestion. In addition, this chapter also shows the different price between this two approaches.

Chapter 4 illustrates the design of two case study where are case study on three busses and case study on five busses. Besides that, this chapter also shows the different between two approaches (MCP and LMP) by illustrates the result in table and chart.

Chapter 5 discuss on overall of this research by summarize the entire chapter. Besides that, this chapter also discuss on recommendation in the future for upgrade this research for more details and using ease the method by using software.

CHAPTER 2

POWER SYSTEM ECONOMIC OPERATION OVERVIEW

2.1 Introduction

Power system operation in many electricity supply systems worldwide, has been experiencing dramatic changes due to the ongoing restructuring of the industry. The visible changes have been many, shifting of responsibilities, changes in the areas of influence, shift in the operating objectives and strategies, distribution of work, amongst others.

This chapter looks at the basic aspects of economic operation of a power system from a classical perspective where power generation, transmission and distribution are owned and operated by a single entity. The objective of the system operator, in such scenario, is to satisfy the system load in best possible way, that is, in the most reliable, secure and economic manner. In this environment, the activities of the system operator can be divided over three distinct time periods [6]. Table 2.1 shows the activities of system operator by distinct time period ahead of real time to actual operation.

Table 2.1: The activities of system operator by distinct time period ahead of real time to actual operation

Type	Distinct time period
Pre-dispatch (planning activities)	A week
Dispatch (short term scheduling)	30 minutes
Instantaneous dispatch	5 minutes

2.2 Economic dispatch (ELD)

Economic dispatch is one of the most important and major problem in electrical power systems. Economic dispatch of an electric power system is the determination of the generation allocations in such a manner that minimizes the system total cost while satisfying all operating and physical constraints [7].

Economic dispatch problems have been solved by a set of coordination equations using Lambda-iteration method, the Newton method [8], and the gradient method [9]. A method to calculate the penalty factor which uses load flow Jacobian matrix has also been investigated [10]. The latter approach leads to a set of modified co-ordination equations. A simple scheme normally used to solve the coordination equations is the classical procedure of equal incremental cost method.

The ELD activity is executed in the dispatch stage and it primarily involves allocating the total load between the available generating units in such a way that the total cost of operation is kept at a minimum. An ELD is generally executed every 5 minutes, and hence it is very important that the solution algorithms used is efficient enough. On the other hand, the ELD model should also represent the system is a much detail as possible [1].

2.2.1 Economic power dispatch without considering network losses

The equal incremental principal can be used for the first stage of economic power dispatch. Given the input output characteristic of N generating units are *F1*(*PG1*), *F2*(*PG2*),…, *Fn*(*PGn*), respectively. The total system load is P_D (as shown in Figure 2.1) [11]. The accumulation of the cost of each generation unit will be the total cost of the system. Equality between the total of output power and load demand is the main constraint over the objective function of the system operation, FT. The objective function is to minimize the total cost for supplying the indicated demand PD by allocating the real power generation for each generator [12].

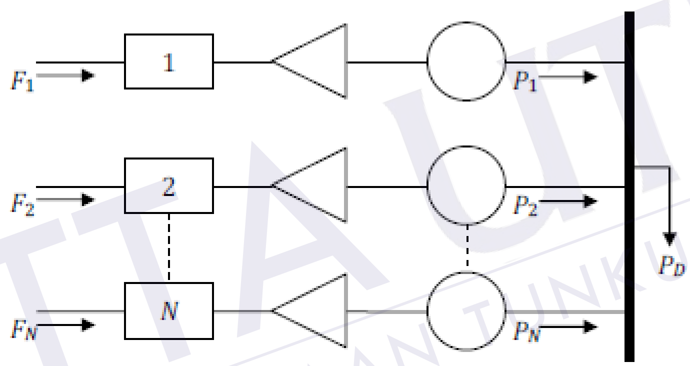

Figure 2.1: N thermal unit committed to serve a load of P_D

Mathematically, the optimization problem which neglects network losses may be stated as

Minimize FT = F (P_{Gi}) = F1 + F2 + F3 + … + FN

$$= \sum_{I=1}^{N} F_i(P_{Gi})$$

Subject to:

- the energy balance equation

$$\varepsilon = 0 = P_D - \sum_{i=1}^{N} P_{Gi}$$

- the inequality constraints

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \qquad (i = 1,2, \ldots, N)$$

The above constrained optimization problem and can be solved by using an advanced calculus method involving Lagrange function. Lagrange function is formed by adding the constraint function to the objective function once the constraint function has been multiplied with a Lagrange multiplier, as formulated in (2.2). This multiplier may be used for either minimizing or maximizing with side condition in the form of equality constraint.

$$L = F_T + \lambda \, \varepsilon \qquad (2.2)$$

$$L(P_{Gi}\lambda) = F(P_{Gi}) + \lambda(P_D - \sum_{i=1}^{N} P_{Gi}) \qquad (2.3)$$

Where λ is the Lagrangian multiplier.
The first partial derivative of the Lagrange function with respect to energy balance constraint to have the necessary conditions for an extreme value of the objective function at particular spot,P_{Gi}^{*}. The derivation should equal zero in order for the objective function to reach minimum or maximum value.

2.2.2 Economic power dispatch considering network losses

The configuration of the economic dispatch problem with network losses considered is slightly more intricate to set up compared to the dispatching ignoring losses. This is because the network losses are added as an additional constraint to the equation. Figure 2.2 illustrates a thermal power generation system connected to an equivalent load bus through a transmission network.

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